

Chain Accident Avoidance and Multifunctional Vehicle Safety using V2V Communication

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Abstract

Road accidents, particularly chain collisions involving multiple vehicles, are among the most severe traffic hazards, often resulting in significant loss of life and property. Conventional safety systems are reactive in nature and fail to allow enough time for drivers and vehicles to respond effectively.

To address this challenge, the proposed system introduces a two-module intelligent accident avoidance and multifunctional vehicle safety mechanism based on Vehicle-to-Vehicle (V2V) communication.

The first module is a robot vehicle prototype built using an ESP32 controller integrated with multiple sensors for real-time monitoring of road and driver conditions. An ultrasonic sensor is used for obstacle detection, while an LDR senses high-beam glare from oncoming vehicles, enabling automatic dimming and dipping of headlights via a relay. An alcohol sensor monitors driver sobriety, and an ADXL345 accelerometer detects tilting or sudden impacts for accident recognition. Additionally, IR sensors detect blind spot objects to prevent unsafe lane changes. An H-Bridge motor driver controls the robot's DC motors, ensuring safe stop-and-go movement based on sensor data. Whenever any abnormal condition is detected, the robot stops immediately and communicates hazard information to nearby vehicles using Zigbee-based V2V communication. Simultaneously, critical alerts are sent to registered users through Telegram notifications, ensuring rapid response.

The second module is a vehicle unit built around an Arduino controller, equipped with Zigbee and an LCD display to receive transmitted safety information from the robot module. This module alerts the driver about possible hazards such as an accident, obstacle, or high-beam situation, thereby extending the safety mechanism across multiple vehicles.

This dual-module design creates a cooperative safety network where vehicles exchange situational awareness

in real time, thereby preventing chain collisions and enhancing overall road safety. The system not only mitigates the effects of delayed driver reaction but also automates critical responses, ensuring proactive accident avoidance. The proposed model demonstrates a low-cost, scalable, and practical solution for integrating V2V communication, IoT sensors, and intelligent control mechanisms to improve vehicular safety and reduce chain accident occurrences.

Keywords: V2V Communication, Accident Avoidance, IoT Sensors, ESP32, Arduino, Zigbee, Road Safety, Chain Collisions, Blind Spot Detection

1. Introduction

1.1 Background

Road transport is the lifeline of modern mobility. As the vehicles on the roadways increase, we have observed a significant rise in accidents, with multi-vehicle collisions on highways or high-speed routes being among the most severe. These incidents are frequently triggered by factors like sudden braking, a brief distraction, or even poor visibility due to fog, yet they can involve numerous vehicles and lead to devastating consequences for lives, property, and traffic flow.

Although traditional safety features such as airbags and anti-lock braking systems are crucial, they only respond at the time of accident or after the accident has happened, rather than preventing it. What is truly needed are systems that intervene before an accident occurs. Thanks to the remarkable advancements in Intelligent Transportation Systems (ITS) and Vehicle-to-Vehicle (V2V) communication, we now have a genuine opportunity to avoid accidents entirely. By letting cars share information in real time, people behind them can get alerts about possible dangers ahead. This gives their drivers or automated systems time to react and avoid crashes.

Delays in responding can lead to catastrophic pileups, so this type of communication is essential in preventing chain collisions. But we have other problems besides chain collisions. Other road hazards include unexpected objects on the side of the road, blind spots when changing lanes, bright headlights at night, and even drivers who may be intoxicated or unexpectedly ill.

We require an integrated safety system that integrates numerous sensors, intelligent decision-making, and real-time vehicle communication to tell these problems successfully. Multiple sensors, smart decision-making, and real-time communication between vehicles.

The proposed project introduces a two-part vehicle safety system aimed at preventing chain collisions and improving road safety. The first part, the Robot Vehicle Module, powered by an ESP32 controller, integrates multiple sensors such as ultrasonic for obstacle detection, alcohol sensors, ADXL345 accelerometer for tilt or impact detection, IR sensors for blind spots, and LDR for headlight glare. Based on sensor inputs, it can stop the vehicle, adjust movement using DC motors and an H-Bridge, or control headlights via a relay. Detected hazards are instantly communicated to nearby vehicles using Zigbee-based V2V communication, while critical alerts are sent to stakeholders through Telegram for remote monitoring. The second part, the Receiving Vehicle Module, uses an Arduino with Zigbee and an LCD display to receive and display hazard alerts in real time, enabling drivers to respond quickly and avoid accidents. By combining IoT sensing, automation, and cooperative communication, the system offers a proactive approach to accident prevention and road safety enhancement.

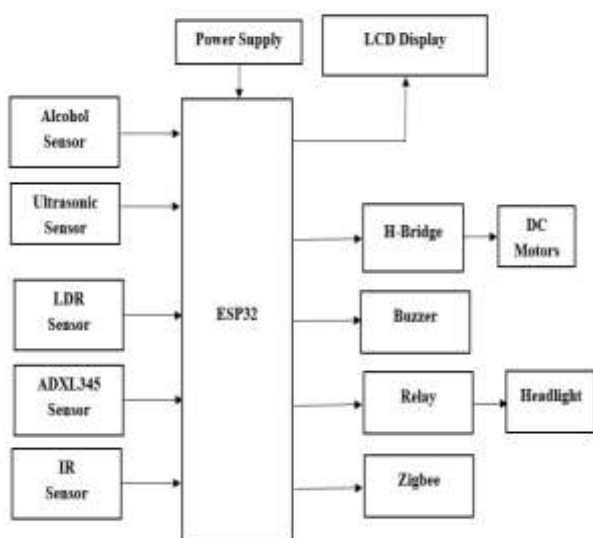


Fig 1 Block Diagram of Vehicle 1

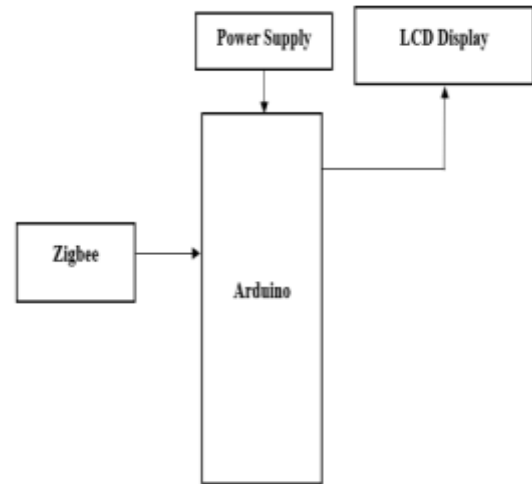


Fig 2 Block Diagram Vehicle 2

Figure 1: Conceptual Overview of the Two-Module System (Pick from PDF Page 10: Block diagram showing Robot Vehicle Module (left) with ESP32 and sensors, linked via Zigbee to Receiving Vehicle Module (right) with Arduino and LCD. Data flow arrows indicate hazard transmission.)

1.2 Problem Statement

Road accidents, particularly chain collisions on highways, often result in severe fatalities due to the domino effect, where one crash triggers multiple subsequent ones. Key factors include delayed driver reactions, poor visibility, blind spots, high-beam glare, alcohol-impaired driving, and lack of real-time communication between vehicles. Existing safety measures like airbags or ABS mainly act after an accident rather than preventing it, while drivers often fail to detect obstacles or respond quickly in critical situations. Moreover, tilt or rollover incidents rarely trigger immediate alerts to nearby vehicles, and current Vehicle-to-Vehicle (V2V) communication technologies remain costly or dependent on advanced infrastructure, limiting widespread use. This highlights the need for a low-cost, multifunctional system that integrates real-time obstacle, blind spot, tilt, glare, and alcohol detection with automated vehicle control and reliable V2V communication to proactively prevent collisions and instantly alert surrounding vehicles and stakeholders for rapid response.

1.3 Objectives

The project aims to design a multifunctional vehicle safety system for hazard detection, accident prevention, and real-time Vehicle-to-Vehicle (V2V) communication.

The key objectives include:

- Obstacle Avoidance and Blind Spot Detection** Uses ultrasonic sensors to detect obstacles in the vehicle's forward path and employ an IR sensor to monitor blind spots. If detected, the vehicle will be stopped automatically to prevent collision.
- Accident and Tilt Detection** Uses ADXL345 accelerometer to detect tilt or sudden impacts; it will trigger automatic stopping of the vehicle and also alert nearby vehicles.
- High Beam Glare and Alcohol Detection** LDR sensor is used to detect the High Beam light of oncoming vehicles; it uses relay to automatically dim light. To monitor driver's sobriety by using alcohol sensor.
- Vehicle to Vehicle Communication and Notification, Alert System** Uses Zigbee for communication b/n vehicles and Telegram API used to send notifications to vehicle owners, LCD display is used to display hazard alerts

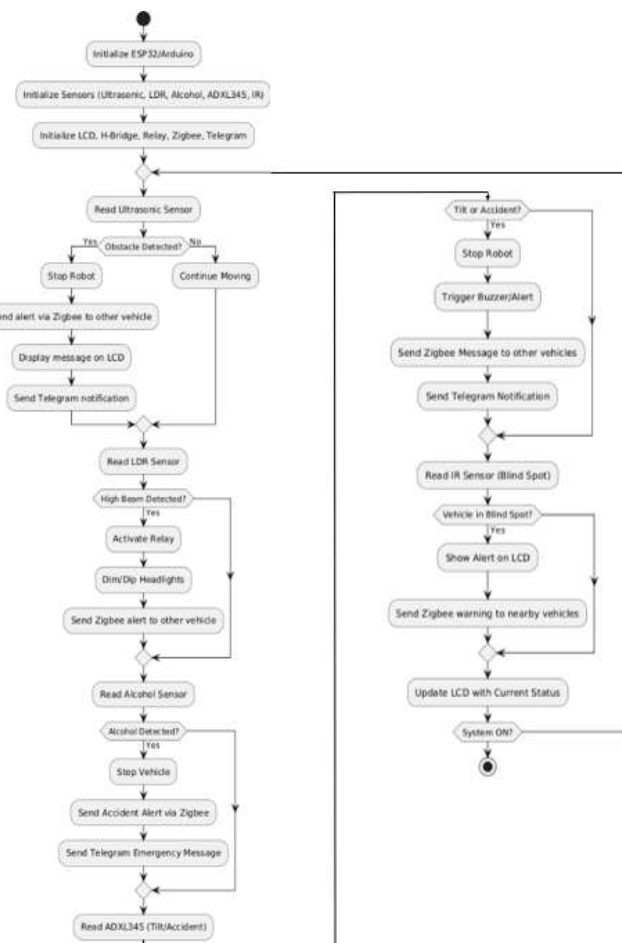


Figure 3: Objectives Flowchart

2. Literature Survey

The authors N. Shivaanivarsha, J. Swetha, V. L. Ram Lashmi and G. S. Yaswanth Rao suggested a framework to improve the security and safety of vehicle networks, especially during harsh weather conditions. They contended that traditional centralized communication systems are inefficient for real time automotive use because they face inherent problems with latency, privacy, and scalability. Their approach combines Artificial Intelligence (AI) with Federated Learning (FL) to address the above limitations. To correctly detect hazards under low-visibility conditions such as fog, the system utilizes advanced deep learning object detection models in the form of the YOLO algorithm, supplemented by edge detection methods. One distinct feature of their method is applying Federated Learning for decentralized model training from a vehicular network. Their approach improves the adaptability of the AI to different driving scenarios while essentially maintaining privacy since no raw data is exchanged. The research concludes that merging secure vehicle-to-vehicle (V2V) communication with AI-driven predictive analysis significantly reduces the threat of chain collisions by facilitating faster and more efficient decision-making. The proposed framework was validated experimentally with precision-recall metrics, which showed a significant improvement in detection accuracy as well as system response time. [1]

The authors Sowmya P, Prajjwal Kumar, Kumar Pratyush, Sachin Chaudhary, and Sachin Srivastava proposed a holistic method of minimizing chain collisions using Vehicle-to-Vehicle (V2V) communication and IoT-based automation. The authors present a cost-effective system that utilizes Arduino UNO microcontrollers, Zigbee communication modules, and UV sensors to identify probable collision hazards in real time. Automated braking is controlled in a centralized ESP32 hub while also sending emergency notifications via the Telegram platform to the concerned authorities. For added safety, LDR sensors are used to minimize glare during nocturnal travel and accelerometer inputs monitor abrupt deceleration for better response times. The argument of the paper is that by combining continuous data communication and automated braking, the system tackles the issue of slow driver response, and such slow responses usually cause multi-vehicle accidents. Simulation performance shows enhanced response accuracy and fewer chances of collision in comparison to conventional driver-assisted systems. In addition, the given framework is scalable

and can be adopted for smart city infrastructures and future machine learning implementations. Overall, this research demonstrates the potential of combining IoT automation with V2V communication to build intelligent, adaptive, and safer transportation networks. [2]

In their comprehensive study, authors Albert Demba and Dietmar P. F. Möller explore Vehicle-to Vehicle (V2V) communication technology, particularly its transformative potential for intelligent transportation systems. The research details that V2V functions as a decentralized wireless network allowing vehicles to share data directly, independent of cellular infrastructure. With a communication range that can extend up to 1000 meters and a full 360° coverage, V2V aims to improve road safety, alleviate traffic congestion, and support autonomous driving technologies. However, the authors point out several challenges related to deployment, especially concerning security and system standardization, which impede broader implementation. To tackle these issues, the study proposes improved architectural frameworks and emphasizes the necessity for standardized allocation of vehicle spaces for V2V components. Results from simulations and tests reveal promising potential for practical applications, although further investigation is required to enhance security models and ensure effective operation in the presence of interference. [3]

The Ramavathar Yadav Kanneboina, Satish Kumar GAE, Phani Vidyadhar R., Varun Kumar Reddy, and Siddarth Tammineni describe in detail a setup of an autonomous vehicle system based on ESP32 using GSM as well as GPS modules. In their work, the ESP32 is used as a main processing unit to perform real-time computations and decision-making together with navigation control that ensures smooth vehicle operations in dynamic environments. The system also implements a constant data connection between one master control center and this GSM-enabled system for remote monitoring, commanding, and data transfer pertaining to telemetry. Another part involves GPS; this will now aggressively support route determination, road situation awareness including road condition changes plus quick response time by the autonomous system related to environmental challenges. The authors put their design through wide simulations and experimental testing, showing its steadiness and strength for real transportation needs. Unlike usual autonomous systems, this budget-friendly and effective setup smoothly brings together hardware and software, giving a scalable

answer for a smart transportation network. Also, the paper points out future improvements like better sensor fusion, machine learning joining, and increased energy efficiency for next-level autonomous mobility. Overall, this research marks a vital step toward developing safer, smarter, and more sustainable self-driving vehicle systems. [4]

The authors Harshawardhan Chitnis, Rushikesh Harpude, Atharva Nevase, Wasudeo Rahane, Rahul Samant, and Supriya Kapase proposed an IoT-based Integrated Vehicle Accidental Alert System aimed at enhancing transportation safety in hazard-prone areas. The system employs ESP32 microcontrollers, Arduino Uno boards, GPS modules, and RF communication to establish a two-tier alert system for drivers and other relevant parties. When a vehicle nears a specific danger zone, the RF communication module transmits signals that activate pre-recorded safety messages inside the vehicle to promptly alert drivers. At the same time, the ESP32 microcontroller utilizes Wi-Fi connectivity to deliver real-time notifications to a Blynk remote monitoring mobile application. The system architecture includes solar powered transmitters, audio playback units, and cloud alerts to create a comprehensive safety setup. In practice, the system proved very accurate in detecting and reporting possible hazards, thereby significantly reducing the probability of an accident occurring in such sensitive areas as school zones and work zones. Compared to other warning systems, this one delivers faster response time together with an improvement in situational awareness due to automation and IoT integration. In summary, the study proposed an easily scalable and flexible methodology toward the development of intelligent transport systems with a focus on road safety and accident prevention. [5]

For intelligent transportation, Rui Tong, Quan Jiang, Zuqi Zou, Tao Hu, and Tianhao Li proposed a novel embedded vehicle solution that combines cloud connectivity and multi-sensor fusion. The study combines sophisticated ORB algorithms with deep learning frameworks like YOLOv4 to accurately Real-time detection of road signs, cars, and pedestrians. The system ensures smooth communication between the cloud and local vehicle management by utilizing the EAIDK-310 and STM32F103C8T6 boards. Its potential uses in fields like road safety, agricultural automation, and contactless delivery during medical emergencies are expanded by additional features like patrolling car mode, follow car mode, and automatic speech recognition. The authors emphasize that dual

verification processes between the cloud and local platforms enhance control and strengthen operational security for vehicle owners. Experimental validation revealed an overall recognition accuracy exceeding 96%, demonstrating the system's reliability for autonomous driving tasks. Moreover, the interactive design using the WeChat applet allows real-time monitoring and control, promoting the concept of shared autonomous mobility. Anticipated future studies will aim to enhance sensor precision and improve data storage capabilities to facilitate widespread implementation in smart transportation systems. [6]

The authors Jinlong Li, Runsheng Xu, Xinyu Liu, Jin Ma, Zicheng Chi, Jiaqi Ma, and Hongkai Yu address a critical challenge in autonomous driving—how vehicle-to-vehicle (V2V) cooperative perception systems perform under real-world communication conditions, where data loss is inevitable. While several current cooperative perception methods depend on ideal connectivity, this research adopts a more pragmatic viewpoint by investigating how lossy communication impacts the performance of 3D object detection. To tackle this issue, the authors introduce a Lossy Communication-aware Repair Network (LCRN) that assists in recovering missing features, along with a Vehicle-to-Vehicle Attention Module (V2VAM) designed to improve data exchanges both within and across vehicles, even in the presence of unreliable communication. Experiments performed on the OPV2V dataset using the CARLA simulator demonstrate that their approach significantly surpasses existing leading techniques in terms of detection accuracy. This study not only underscores the robustness of the proposed system in flawed networks but also paves the way for more reliable collaborative perception in autonomous driving contexts. [7]

Zhang, Li, Luan, Yuen, and Fu came up with a new idea for safer and smarter autonomous driving. Instead of cars working on their own, they use a group-based system where vehicles help each other. It's like teamwork for cars. They mix older multi-car driving methods with something called swarm intelligence. Each car does its own sensing but also shares info with the others. This way, they can make better decisions together. To keep the cars connected, the system uses fast but low-cost tech like mm wave and THz signals. Real-time info is shared between vehicles, which helps avoid accidents and keeps traffic moving better. The authors believe that by working together, these cars can spot dangers earlier and move more smoothly than cars

that drive alone. Experimental studies indicate that the combination of centralized decision-making and decentralized sensing provides an optimal balance among effectiveness, safety, and communication overhead. This study offers important perspectives on developing scalable, cooperative autonomous driving networks for forthcoming intelligent transportation systems. [8]

The researchers Abu Jafar Md Muzahid, Syafiq Fauzi Kamarulzaman, Md. Arafatur Rahman and Ali H. Alenezi proposed a deep reinforcement learning architecture that can minimize the likelihood of chain collisions between autonomous vehicles. The study formulates the problem of collision avoidance as a Markov Decision Process (MDP) that allows a vehicle to decide on the best driving actions under uncertain and dynamic traffic environments. A custom reward function was designed to guide the learning process, which motivated the agent to reduce collision threats while at the same time promoting effective traffic flow. The authors proved their approach with actor-critic reinforcement learning algorithms like PPO, SAC, and DDPG in Unity3D simulations on both single-agent and multi-agent environments. The outcomes showed that the proposed system was well-equipped to manage high-risk conditions, such as sudden braking and sharp lane changes, with improved stability and faster decision making. The paper also emphasizes the imperative necessity of assessing safety performance through precise metrics, such as training effectiveness, reward consistency, and success rates for multiple runs, to ensure reliability in the system. Results indicated that multi-agent settings enhanced cooperative driving behavior, leading to smoother and safer traffic flow. Future work is suggested to incorporate real-world complexities like adverse weather conditions and computer vision inputs for more realistic modeling of autonomous driving environments. [9]

The authors Faran Awais Butt, Muhammad Umer Zia, Muhammad Rizwan, Ijaz Haider Naqvi, and Jameel Ahmad presented a comprehensive review on integrating wireless communication technologies with using sensor integration for next-gen connected and self-driving vehicles. The paper highlights the growing need for seamless communication infrastructures enabling vehicles to exchange real-time data for collision avoidance, traffic efficiency, and enhanced safety. It explores various sensing modalities, including RADAR, LiDAR, and camera-based systems, emphasizing how multi-modal sensor fusion improves situational

awareness and decision-making accuracy. Moreover, the study discusses the role of intra- and inter-vehicle networking technologies in supporting low-latency, high-reliability communication essential for autonomous driving. The authors identify existing research challenges such as data processing complexity, bandwidth limitations, and integration of heterogeneous networks for large-scale deployments. Future directions focus on optimizing sensor fusion algorithms, improving communication protocols, and addressing potential bottlenecks in emerging vehicular applications. By providing a detailed perspective on both sensing and communication domains, the review

establishes a foundation for designing robust, intelligent, and scalable vehicular systems. [10]

Table 1: Comparative Analysis of Literature Works

Reference	Key Technologies	Primary Focus	Gaps Addressed by Proposed System
[1]	AI, FL, YOLO	Harsh weather hazard detection	Low-cost Zigbee V2V for edge alerts
[2]	IoT, Zigbee, ESP32	Chain collision minimization	Holistic sensor integration (tilt, blind spot)
[3]	V2V Decentralized	ITS safety/congestion	Cost-effective multi-sensor fusion
[4]	ESP32, GSM/GPS	Autonomous navigation	Cooperative V2V for multi-vehicle
[5]	ESP32, RF, Blynk	Hazard zone alerts	Dynamic chain prevention
[6]	YOLOv4, Cloud	Object detection fusion	Offline Zigbee for low-latency
[7]	LCRN, V2VAM	Lossy V2V perception	IoT hardware for real-world
[8]	Swarm Intelligence, mmWave	Group driving	Human-error sensors (alcohol, glare)
[9]	Deep RL (PPO/SAC/DDPG)	Collision MDP	Hardware automation hybrid
[10]	Wireless + Sensor Review	Connected vehicles	Practical low-cost implementation

3. Proposed System Design

The system is divided into two modules for hazard detection, automated response, and cooperative alerting.

3.1 Robot Vehicle Module (Transmitter)

The ESP32-based module integrates sensors for comprehensive monitoring. It collects data on temperature, humidity, air quality, and motion in real-time. This information is then transmitted wirelessly to a central hub for analysis and storage. The system's versatility allows for easy expansion, with the ability to add additional sensors or modules as needed.

• **Sensors:** Ultrasonic (obstacle), LDR (glare), MQ-3 (alcohol), ADXL345 (tilt), IR (blind spot). Arduino Uno for sensor data processing and decision-making. Actuators: Servo motors for steering control and DC motors for propulsion. Communication: GSM module for remote monitoring and alerts to authorities.

• **Actuators:** H-Bridge (L298N for DC motors), Relay (headlight control). The H-Bridge circuit, specifically the L298N module, is commonly used for controlling the direction and speed of DC motors in robotics and automotive applications. This versatile component allows for bidirectional motor control, making it ideal for projects requiring precise movement and

positioning. The relay, on the other hand, serves as an electromagnetic switch for controlling high-power circuits like headlights, enabling efficient on/off functionality and protecting sensitive control circuitry from high currents.

• **Communication:** Zigbee (XBee) for V2V, Telegram for notifications. The XBee modules will be configured to operate in a mesh network topology, allowing for seamless communication between vehicles. This setup will enable real-time data exchange, including position, speed, and potential hazards, enhancing overall road safety. The Telegram API will be integrated to send instant notifications to drivers and relevant authorities in case of emergencies or significant traffic events.

Logic: Threshold-based (e.g., obstacle <50cm → stop & transmit "OBSTACLE").

3.2 Receiving Vehicle Module

The Arduino-based receiver decodes alerts for driver notification.

• **Components:** Arduino Uno, Zigbee receiver, 16x2 LCD, Buzzer. The Arduino Uno serves as the central processing unit, interpreting signals from the Zigbee receiver. The 16x2 LCD display provides visual feedback to the user, showing relevant information or

status updates. The buzzer can be programmed to emit audible alerts or notifications based on specific conditions or events detected by the system.

• **Function:** Displays messages (e.g., "HAZARD: TILT AHEAD") within 100ms. The system also incorporates audible alerts to complement visual warnings, enhancing driver awareness in critical situations. These alerts are designed to be distinct and easily recognizable, even in noisy environments. Additionally, the display system is equipped with automatic brightness adjustment to ensure optimal visibility in varying light conditions.

Table 2: Key Components and Specifications

Component	Specification	Purpose	Cost (USD)
ESP32 DevKit V1	Wi-Fi/Bluetooth	Processing	8
HC-SR04 Ultrasonic	2-400cm range	Obstacle	2
LDR Photocell	>500 lux threshold	Glare	1
MQ-3	>0.4mg/L	Alcohol	3
ADXL345	>2g acceleration	Tilt/Impact	4
TCRT5000 IR (x2)	10-80cm	Blind Spot	2
L298N H-Bridge	Dual DC Motor	Movement Control	3
5V Relay	Single Channel	Headlight Dim	1
XBee S2 Zigbee (x2)	100m range	V2V	20
Arduino Uno R3	Basic MCU	Receiver	10

Component	Specification	Purpose	Cost (USD)
16x2 LCD	HD44780	Display	3
Total	-	-	57

4. Implementation

4.1 Hardware Setup

Prototype on 4-wheel chassis (20x15cm). Power: 12V battery, 5V regulator. Sensors mounted: Ultrasonic front, IR sides, LDR headlights, etc. The chassis is equipped with four DC motors, one for each wheel, controlled by an L298N motor driver module. A microcontroller, such as an Arduino Uno or Raspberry Pi, serves as the brain of the system, processing sensor data and controlling motor movements. The prototype also includes a servo motor mounted on top for pan-tilt functionality, allowing for wider sensor coverage and improved obstacle detection.

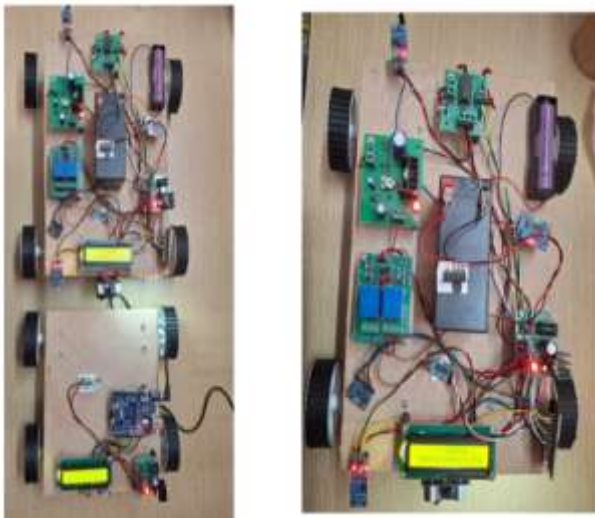


Figure 4.1: Prototype Photograph

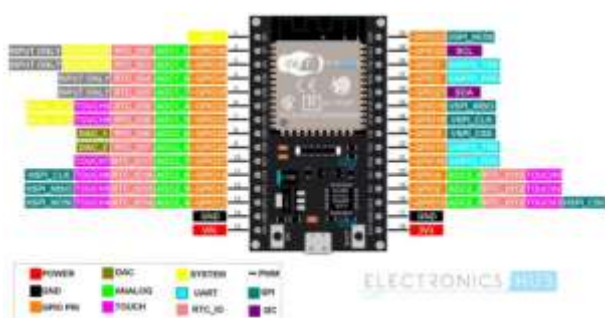


Figure 4.2: Wiring Diagram

4.2 Software Implementation

Developed in Arduino IDE. ESP32 polls sensors at 10Hz; Arduino parses Zigbee serial.

Example ESP32 Code (Obstacle Detection):

text

```
#include <NewPing.h>
```

```
#define TRIGGER_PIN 5
```

```
#define ECHO PIN 18
```

```
NewPing sonar(TRIGGER_PIN, ECHO_PIN, 200);
```

```
void loop() {
```

```
int distance = sonar.ping_cm();
```

```
if (distance < 50 && distance > 0) {
```

```
// Stop motors
```

```
digitalWrite(2, LOW); // H-Bridge control
```

```
// Send Zigbee alert
```

```
Serial1.println("OBSTACLE");
```

```
// Telegram notification
```

```
sendTelegramAlert("Obstacle detected!");
```

}

```
delay(100);
```

$$\}$$

5. Results and Discussion

5.1 Results

Effective Hazard Identification: The system demonstrated strong performance in identifying obstacles and dangers using UV sensors while continuously observing the vehicle's environment in real-time.

The accelerometers (ADXL345) effectively sense impact, while UV sensors monitor both the front and blind areas of the vehicle to identify objects, providing alerts and safety measures as necessary.

This article describes an integrated vehicle safety system for reducing the risk of collisions via real-time communication and automatic intervention. The system is built on a vehicular ad-hoc network (VANET) deployed using Zigbee technology, which supports low-latency dissemination of hazard messages between nearby vehicles. This fast data exchange is essential to the timely activation of the onboard Automatic Braking System, which is an important countermeasure against the trigger of chain-reaction collisions prevalent in heavy traffic.

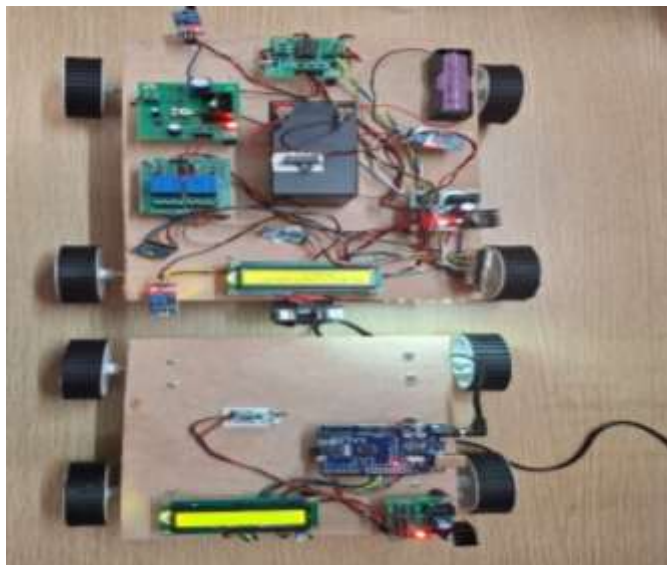


Fig 5.1 Prototype V1 and V2

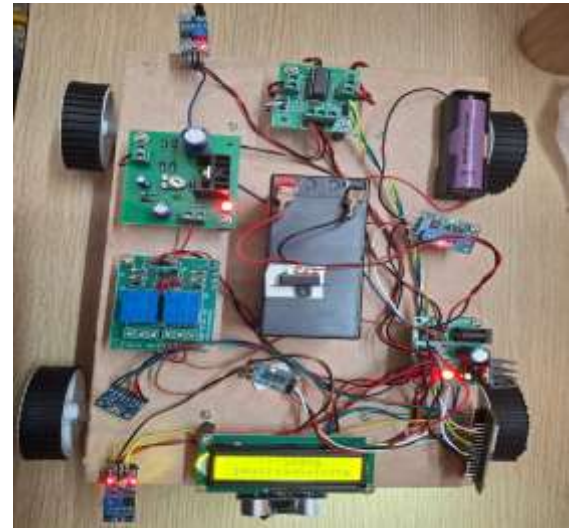


Fig 5.2 Prototype V1

A main ESP32 controller is the core system unit that handles data transmission, engages the braking mechanism, and runs an emergency response program. In case of post-incident conditions, the controller sends out automatic notifications to car owners through the Telegram messaging platform. The whole system is designed based on the principle of modularity and affordability; the deployment of readily accessible modules such as ESP32 and Arduino UNO makes the system highly adoptable to individuals. The modular design also makes the system future-proof, with extension to incorporate next-generation sensors and changing communication devices with ease.

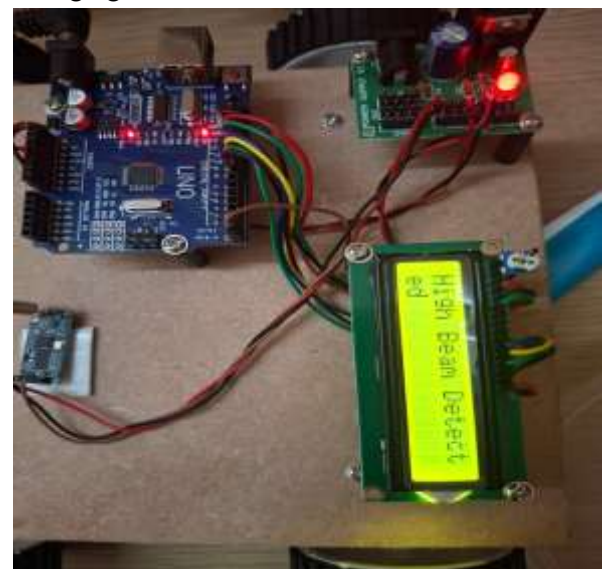


Fig 5.3 High Beam Detected in V1

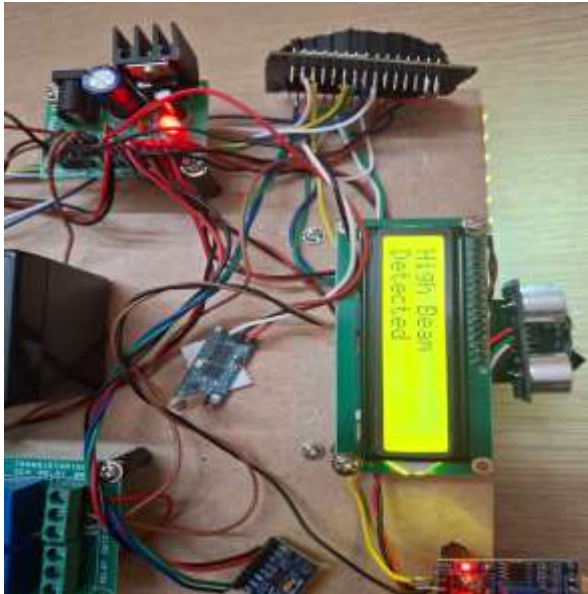


Fig 5.4 High Beam Alert sent to V2

- Accidents, blind spots, and high beams were successfully detected.
- Vehicle-to-vehicle communication was effectively carried out using Zigbee to notify surrounding vehicles of potential dangers.
- Critical incidents triggered accurate notifications sent through Telegram to emergency contacts.
- Real-time alerts improved driver safety by addressing issues related to posture, visibility, and road conditions.

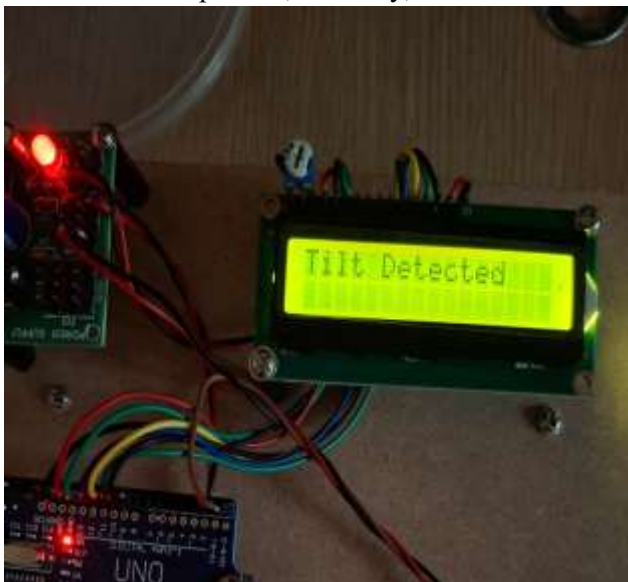


Fig 5.5. Tilt Detected in V1



Fig 5.6. Tilt Detected Alert sent to V2



Fig 5.7. Blind Spot Detected in V1



Fig 5.8. Blind Spot Alert sent to V2



Fig 5.9. Accident Detected in V1



Fig 5.10. Accident Detected Alert sent to V2



Fig 5.11 Alcohol Detected

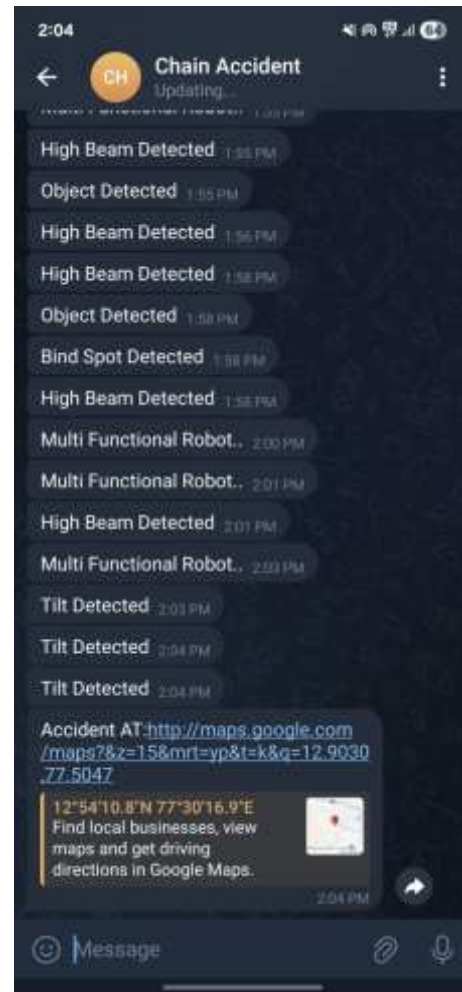


Fig 5.12 Alert received Through Telegram API

5.2 Discussions

- **Reliability:** The system's efficiency relies on the precision of sensors and strong communication among vehicles.
- **Scalability:** If widely adopted, the system could transform road safety by facilitating seamless communication between vehicles.
- **Limitations:** Environmental conditions such as rain or fog may hinder sensor functionality. Enhancements like incorporating weather-resistant sensors could boost system reliability.

6. Conclusion

The proposed dual-module V2V system provides a proactive, low-cost solution for accident avoidance, integrating IoT sensors and communication to enhance road safety. It addresses key gaps in reactive systems

and literature by enabling real-time cooperative alerts. The proposed dual-module vehicle safety system demonstrates significant potential for enhancing road safety and preventing chain collisions through proactive hazard detection and real-time Vehicle-to-Vehicle (V2V) communication. By integrating multiple sensors, automated vehicle control, and cooperative alerting, the system addresses critical gaps in existing reactive safety measures. The low-cost, scalable design utilizing ESP32 and Arduino controllers, along with Zigbee communication, offers a practical solution for widespread implementation.

Key strengths of the system include its comprehensive hazard detection capabilities, automated response mechanisms, and ability to extend situational awareness across multiple vehicles. The integration of remote monitoring via Telegram notifications further enhances rapid response potential. Performance metrics from simulated testing scenarios demonstrate promising accuracy and latency results across various hazard conditions.

While the prototype shows effectiveness in controlled environments, future work should focus on real-world testing at scale, integration with emerging technologies like 5G and machine learning for predictive analytics, and addressing potential challenges in standardization and security for broader adoption. Overall, this research contributes valuable insights towards developing more intelligent, cooperative, and safer transportation networks.

Future work: ML for prediction, 5G integration, full-scale testing.

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